Solubility of Chrysotile Asbestos and Basalt Fibers in Relation to their Fibrogenic and Carcinogenic Action

F. M. Kogan and O. V. Nikitina

Medical Research Center for Health Protection of Industrial Workers, Ekaterinburg, Russia

Fiber length and persistence are thought to be determinants for the development of toxic, fibrogenic, and carcinogenic effects of fibrous dusts. When the solubilities of chrysotile asbestos (CA) and basalt fibers (BF) were compared by measuring the loss of silica and magnesium in Leineweber's solution, CA was shown to be the more soluble. In a 6-month inhalation experiment, chrysotile at a mean concentration of 25 mg/m^3 had a higher clearance rate than other comparable dusts. In acute toxicity studies, chrysotile and basalt fibers were administered intraperitoneally. At a dose of 1.7 g/kg body weight of CA, one third of the animals died. A dose of 2.7 g/kg body weight killed all the animals. With BF, even at a dose of 10 g/kg body weight all the animals survived. When the two fibers were administered over a 6-month period, either intratracheally or by inhalation, fibrotic lesions were more common in the group that received CA. Intraperitoneal administration of CA led to three times as many deaths from peritoneal mesothelioma as administration of BF. It appears, therefore, that in spite of its higher solubility and lower persistence, CA was the more toxic, fibrogenic, and carcinogenic fiber, which gives rise to the hypothesis that the surface chemistry of the fibers is the determinant for biological activity. — Environ Health Perspect 102(Suppl 5):205–206 (1994)

Key words: solubility, persistence, chrysotile asbestos, basalt fibers,oncogenicity, toxicity, fibrogenicity

Introduction

Many studies have demonstrated that fiber length and durability were determinant in fiber-induced carcinogenesis (*1–3*). Epidemiological studies of tumor frequency in workers exposed to airborne asbestos or MMMF neither confirm nor refute that conclusion. Nevertheless, the selective retention of long, thin fibers in the lungs of workers who had died from asbestos-induced tumors, would indicate that it is their higher persistence, in contrast to the relatively rapidly-cleared short fibers, that is responsible for their carcinogenicity.

Experiments with basalt fibers of various sizes and particularly different diameters were not able to distinguish differences in carcinogenicity (*4*). Another experiment (*5*), in which asbestos was contained in an artificially constructed pocket in the glandular stomach of the rat, resulted in many malignant stomach tumors, yet when asbestos was administered in food and water to rats during a long period, no tumors were seen.

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Address correspondence to F. M. Kogan, Medical Research Center for Health Protection of Industrial Workers, Ekaterinburg, Russia.

Results

Fiber Composition

The fibers used in this study were chrysotile asbestos (CA) from the Central Urals deposit and basalt fiber (BF) that can be used as a substitute for chrysotile in certain materials. BF exists in three nominal diameters: micro BF (M), diameter 0.6 μm; ultra BF (U), diameter 0.6 to 1.0 μm; and superthin (S), 1 to 3 μm.

Examination under phase contrast optical microscopy ×450, showed BF(S) sampled to contain 11.5% of fibers, of which 17.2% were of respirable size; BF(U) contained 12.1% of fibers, of which 41% were respirable; and BF(M), 13.5% with 45.2% respirable. The CA sample consisted of 11.1% of fibrous particles with 76% respirable. The remaining particles were granular, predominantly serpentinite and peridotite. The chemical compositions are given in Table 1.

Solubility

The solubility of the fibers was studied in Leineweber's solution (Table 2) at 37°C. The dissolution of silica was determined by measuring silicic acid in the solution by a photometric technique based on the intense blue of the silica molybdenum complex; the dissolution of magnesium was determined by a colorimetric technique using titanium yellow as an indicator.

Both the BF(U) and BF(S) were less soluble than chrysotile, as judged by the percentage by weight of silica and magnesium that passed into solution during 15 days exposure (Table 3). Based on this observation, BF dusts could be considered more persistent than chrysotile and therefore biologically more aggressive.

Table 1. Chemical contents of the two fiber types.

Chemical	Weight, % Basalt fiber	Weight, % Chrysotile asbestos
SiO_2	49.9	42.1
Al_2O_3	21.3	0.53
TiO_2	1.4	—
Fe_2O_3	9.7	0.24
CaO	9.7	trace
MgO	6.5	41.99
P_2O_3	0.2	—
$Na_2O + K_2O$	—	trace
H_2O (of crystallization)	—	12.99

Table 2. Chemical composition of Leineweber's solution.

Chemicals	g/l of water
NaCl	6.78
NH_4Cl	0.535
$NaHCO_3$	2.268
$NaH_2PO_4(x\ H_2O)$	0.168
Na citrate	0.059
Glycine	0.45
H_2SO_4	0.049
$CaCl_2$	0.22

Table 3. Solubility of two constituents of the basalt fibers and chrysotile asbestos dusts in Leineweber's solution, mg%.

	Duration of contact, days							
	1		3		10		15	
	SiO_2	Mg	SiO_2	Mg	SiO_2	Mg	SiO_2	Mg
Basalt fibers, superthin	13.0	0.04	13.0	0.06	13.0	0.06	13.0	0.06
Basalt fibers, ultrathin	13.0	0	13.0	0.04	13.0	0.06	14.0	0.10
Chrysotile asbestos	22.1	2.0	22.0	2.0	22.0	3.2	29.1	5.0

Table 4. Weight of fibers retained in rat lungs after intratracheal instillation of 55 mg of chrysotile asbestos or basalt fiber dusts per rat.

	Weight of fiber mg/100 mg dry lung	
Time after instillation	3 months	6 months
Chrysotile asbestos	10.7 ± 0.5	8.4
Basalt fiber	11.1–15.5	11.0–11.4

Retention

Administration by Intratracheal Instillation. Rats were treated with 55 mg of CA and BF by intratracheal administration. One group was sacrificed after 3 months, the other after 6 months. In each case the lungs were removed and dried, and the fiber content determined in a 100-mg sample of dried lung.

The results (Table 4) showed that after 6 months the mass of basalt fibers retained was greater than the mass of chrysotile fibers.

Administration by Inhalation. The retention of chrysotile was compared with a granular serpentinite dust, of similar chemical composition. In one experiment, rats were exposed to air containing 113.8 ± 0.13 mg/m^3 of chrysotile or serpentinite, and the lung contents were measured in animals sacrificed 3 months after exposure. For an equal weight of dry lung, the mean weight of chrysotile fibers was 3.34 mg, compared with 20.5 mg of serpentinite.

In a second, analogous experiment using guinea pigs, the animals were sacrificed 9 months after exposure. The mean weight of retained chrysotile was 9.9 mg, compared to 36.7 mg for serpentinite.

In all three studies, and based on dust weight, less chrysotile was retained than either basalt or serpentinite; these results accord with earlier studies (*6*) which also showed that chrysotile had a lower retention than other types of asbestos.

Toxicity and Carcinogenicity Studies

Basalt fiber dust, administered to rats by intraperitoneal injection at a dose of 10 g/kg body weight, did not cause any deaths from acute toxicity, but 12 to 14% of the rats developed peritoneal mesotheliomas. In contrast, the toxicity of chrysotile asbestos was sufficient to kill 33% of the animals at a dose of 1.7 g/kg bw, 50% at a dose of 2.2 g/kg bw and 100% of the animals at 6.0 g/kg bw. Moreover, 45% of the test animals developed peritoneal mesotheliomas. When the two types of dusts were administered to rats by intratracheal instillation at doses of 55 mg/rat or by inhalation at doses of 25 mg/m^3, significantly more fibrotic lesions were caused by the chrysotile asbestos. The lesions included diffuse sclerotic changes round the bronchioles and small vessels, and in the alveolar walls.

Conclusion

It is assumed that the higher fibrogenic activity of chrysotile asbestos is due to the greater number of long, thin fibers, which results in a higher specific surface area capable of more effective contact between the fibers and the biosubstratum. Although certain components are leached more readily from chrysotile asbestos than from basalt fibers, suggesting that chrysotile is less persistent, it nevertheless displayed higher acute toxicity and was more fibrogenic and carcinogenic than basalt fiber. This indicates that factors other than solubility and persistence must influence the biological activity of a fiber, and these must relate to the number of fibers per unit mass, to the surface properties of the fiber, and to its interaction with biological structures.

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